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Fuzzy-TOPSIS Based Cluster Head Selection in Mobile Wireless Sensor Networks

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Abstract:

One of the critical parameters of Wireless Sensor Networks (WSNs) is their lifetime. There are various methods to increase WSN lifetime, the clustering technique being one of them. In clustering, selection of a desired percentage of Cluster Heads (CHs) is performed among the sensor nodes (SNs). Selected CHs are responsible for collecting data from their member nodes, aggregate the data and finally send it to the sink. In this paper, we propose a Fuzzy-TOPSIS technique, based on multi criteria decision making, to choose CH efficiently and effectively to maximize the WSN lifetime. We will consider several criteria including: residual energy; node energy consumption rate; number of neighbor nodes; average distance between neighboring nodes; and distance from sink. A threshold based intra-cluster and inter-cluster multi-hop communication mechanism is used to decrease energy consumption. We have also analyzed the impact of node density and different types of mobility strategies in order to investigate impact over WSN lifetime. In order to maximize the load distribution in the WSN, a predictable mobility with octagonal trajectory is proposed. This results in improvement of overall network lifetime and latency. Results shows that the proposed scheme has much better results as compared to conventional selection criteria.

Key words: MCDM, fuzzy-TOPSIS, rank index, clustering, mobile sink, lifetime, stability, throughput.

1 INTRODUCTION

Wireless Sensor Networks (WSNs) consist of a large number of sensor nodes (SNs), randomly deployed to sense and monitor the physical and environmental conditions, as schematically shown in Figure 1. WSNs have become a reality because of development and advancement in micro-electro-mechanical systems (MEMS), resulting in very small SN size, including its wireless communication components [1]. As shown in Fig. 1, there are four main components in WSNs, which include: SNs to accumulate data from the desired geographical area; an interconnection network through which SNs transmit data to a sink/gateway; a central data gathering mechanism (known as a sink); and a set of computing resources at the user end for further storage, processing and analysis [1]. WSNs have numerous applications, such as environmental monitoring, structural health monitoring, military and natural disaster detection and monitoring [2]. Cost-effectiveness in data sensing and gathering is a primary concern. Due to the compactness of wireless SNs, limited power and energy is available; therefore, the efficient and effective utilization of energy in WSNs is required [3].

Clustering is the technique in which selection of a Cluster Head (CH) is performed to preserve energy consumption in WSN. The CH collects data from its member nodes by using a time division multiple access (TDMA) technique and then compresses and aggregates the data in order to remove redundancy. After that, the CH sends compressed and aggregated data to the sink [4]. In this research paper, CH selection is based on Fuzzy-TOPSIS; a Multi Criteria Decision Making (MCDM) technique is proposed. Fuzzy-TOPSIS based CH selection plays a key role for optimizing energy utilization efficiency. Research on the method of Fuzzy Technique for Preference by Similarity to Ideal Solution (Fuzzy-TOPSIS) was performed by Yoon and Hwang in 1981 [5]. TOPSIS is used in business as well as in engineering applications. Fuzzy TOPSIS chooses the best alternatives based on the concept of compromise solution. It chooses the solution with the farthest Euclidean distance from the negative ideal solution and the shortest Euclidean distance from the positive ideal solution. The method consists of forming an $m \times n$ matrix with m number of alternatives and n number of attributes for each alternative [10]. Five criteria are considered in this research paper to select a CH, including remaining energy of the node (residual energy), node energy consumption rate, number of neighbor nodes (node density), average distance between neighboring nodes and distance from the sink. A threshold based intra-cluster and inter-cluster multi-hop communication mechanism is used in order to reduce energy consumption which depends upon whether the distance from the CH or sink is greater than some set threshold. Also, a predictable mobility with

an octagonal trajectory is proposed in order to further maximize the proper load distribution and reduce average latency based on time critical applications in WSNs.

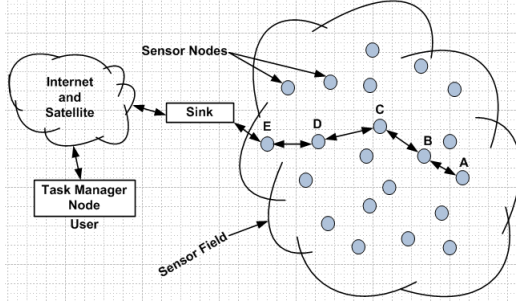


FIGURE 1: A distributed WSN system [1].

The remaining parts of paper are organized as follows: Section II explains related work for energy preservation in clustering algorithms; in section III the proposed scheme with a mathematical model is explained. Simulation, results and analysis are presented in section IV and finally a conclusion of the paper is presented in section V.

2 Related Work

Network lifetime in WSNs is widely improved if a proper clustering algorithm is used for CH selection. A lot of work has been devoted to CH selection, and many clustering algorithms have been proposed.

One of the first CH based algorithms to be proposed was the Low Energy Adaptive Cluster Hierarchy (LEACH) [5]. The LEACH algorithm is divided into two phases: the set up phase; and steady state phase. In the set up phase, numbers of cluster heads are selected among the sensor nodes (SNs) with fixed probability. The selected CHs broadcast advertisement to other nodes within a specific transmission range; the remaining nodes collect multiple broadcast advertisements from different CHs and become a member of a particular CH with high radio signal strength indicator (RSSI) value by sending an associated request. Then CH creates TDMA scheduling, which depends upon the number of member nodes. In the steady state phase, SNs send sensed information to their corresponding CHs, which compress and aggregate the received data and finally send to the sink. After some specific time re-clustering is performed. LEACH performs better as compared to other routing protocols in terms of load balancing and energy efficiency. In [6] the authors propose centralized LEACH (C-LEACH) to further improve the

performance of the LEACH protocol. In C-LEACH the sink selects CHs, instead of SNs themselves. The C-LEACH algorithm gives better results than the LEACH algorithm. In the Hybrid Energy-Efficient Distributed (HEED) Protocol [7], cluster heads are selected based on the nodes' remaining energy and node degree. In the LEACH-Mobile (LEACH-M) paper [8], this protocol provides mobility of SNs. LEACH-M ensures the communication of a mobile node with a CH. In paper [9] the authors have proposed CH selection criteria based on a fuzzy Multiple Attribute Decision Making (MADM) approach. In this protocol a centralized sink centralized is used to select CHs.

The protocols discussed above are based on single or two criteria with mobile nodes or sink selected CHs (centralized). Due to the centralized scheme, nodes periodically send Hello control packets to the sink, which increases control overheads in the network. In this scheme the CH is also changing after every round, and this also increases control overhead packets. In LEACH-M SNs are mobile, which require the sending of Hello control packets more often which increases load on the network.

3 Proposed Scheme

In the proposed scheme, for CH selection, SNs take decisions themselves based on a ranking index value obtained by using five criteria. The selected CH broadcasts an advertisement to its neighboring node within its transmission range. The remaining SNs receive multiple advertisements from different CHs in their transmission ranges, and then decide to associate with the CH which has minimum distance or maximum RSSI value. The proposed scheme makes sure that the CHs are not changed in every round in order to minimize overheads in the set-up phase. Change of CHs depends upon some threshold. If the selected CH threshold value is smaller than the other neighboring nodes, then re-clustering is performed.

The cluster selection process is divided it into six phases, i.e. random deployment of SNs, neighbor nodes discovery, CH selection, CH formation, intra-cluster and inter-cluster multi-hop communication mechanism and finally sink mobility with predictable octagonal and random trajectory. The detailed procedure of the proposed scheme is explained below.

3.1 Phase-1:

Initially all SNs are deployed randomly in the WSN field because it is considered a simple and low-cost strategy of deployment, as shown in Fig. 2(a). After deployment, the sink node broadcasts a Hello control packet in the network, which contains information about its location.

3.2 Phase 2:

Neighbor discovery is performed in phase 2; all SNs broadcast a Hello control packet in their transmission range T_R , by using the carrier sense multiple access (CSMA) technique. The Hello control packet contains important information such as: residual energy (criteria-1, C_1); node energy consumption rate, C_2 ; node density, C_3 ; average distance between this node and its neighbor nodes, C_4 ; distance from the sink node, C_5 ; node location and ID information. Initially, the node has no information about its neighbors, so C_2 , C_3 and C_4 fields are kept empty in the Hello control packet. All SNs update their neighborhood table after receiving the Hello control packet from neighboring nodes as shown in Eq. 1.

3.3 Phase 3:

CH selection is performed in phase 3, using the fuzzy-TOPSIS method. As all values in the neighborhood table are not in the same range, the values must be normalized to a similar range in order to fairly select a CH. In C_1 and C_3 larger values are desired to select CH, so these values are normalized with Eq. 2. On the other hand, for C_2 , C_4 and C_5 smaller values are desired to select CH, so these values are normalized with Eq. 3. Then a weighted decision matrix is formed by assigning criteria weights to each value of normalized matrix X_k . After that, maximum and minimum values are calculated from Eq. 6 and Eq. 7, respectively. The separation measures are calculated with the help of the n-dimensional Euclidean distances of each alternative using the fuzzy negative ideal solution (FNIS) and fuzzy positive ideal solution (FPIS) which are shown in Eq. 8 and 9, respectively. Finally, the Rank Index (R.I.) is calculated. The node with the highest R.I. in its transmission range will be selected as the CH.

$$T_k = \begin{matrix} & C_1 & C_2 & C_3 & C_4 & C_5 \\ \begin{matrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_{n+1} \end{matrix} & \begin{pmatrix} x_{1,1} & x_{1,2} & x_{1,3} & x_{1,4} & x_{1,5} \\ x_{2,1} & x_{2,2} & x_{2,3} & x_{2,4} & x_{2,5} \\ x_{3,1} & x_{3,2} & x_{3,3} & x_{3,4} & x_{3,5} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{n+1,1} & x_{n+1,2} & x_{n+1,3} & x_{n+1,4} & x_{n+1,5} \end{pmatrix} \end{matrix} \quad (1)$$

where, T_k is the neighborhood table for node k and n is number of nodes.

$$X_{ij} = \frac{x_{ij} - \min_{\forall i}(x_{i,j})}{[\max_{\forall i}(x_{i,j}) - \min_{\forall i}(x_{i,j})]} \quad (2)$$

$$X_{ij} = \frac{\max_{\forall i}(x_{ij}) - x_{ij}}{[\max_{\forall i}(x_{ij}) - \min_{\forall i}(x_{ij})]} \quad (3)$$

$$X_k = \begin{pmatrix} X_{1,1} & X_{1,2} & X_{1,3} & X_{1,4} & X_{1,5} \\ X_{2,1} & X_{2,2} & X_{2,3} & X_{2,4} & X_{2,5} \\ X_{3,1} & X_{3,2} & X_{3,3} & X_{3,4} & X_{3,5} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{n+1,1} & X_{n+1,2} & X_{n+1,3} & X_{n+1,4} & X_{n+1,5} \end{pmatrix} \quad (4)$$

where, X_k is normalized matrix for node k.

After normalization of the decision matrix, each value is replaced according to its rank value, and then transformed to fuzzy membership functions as shown in Table I but is not easy to assign exact values of the SNs for each fuzzy membership function. Thus we have the processing sequence described by:

$$X = \begin{pmatrix} X_{11} & X_{12} & X_{13} & X_{14} & X_{15} \\ X_{21} & X_{22} & X_{23} & X_{24} & X_{25} \\ X_{31} & X_{32} & X_{33} & X_{34} & X_{35} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ X_{(n+1)1} & X_{(n+1)2} & X_{(n+1)3} & X_{(n+1)4} & X_{(n+1)5} \end{pmatrix} \quad (5)$$

where, X is the weighted decision matrix.

$$\begin{aligned} FPIS &= (X_1^+, X_2^+, \dots, X_n^+) \\ &= [(\max_i X_{ij} | i = 1, \dots, m), j \\ &= 1.., (n + 1)] \end{aligned} \quad (6)$$

$$\begin{aligned} FNIS &= (X_1^-, X_2^-, \dots, X_n^-) \\ &= [(\min_i X_{ij} | i = 1, \dots, m), j \\ &= 1.., (n + 1)] \end{aligned} \quad (7)$$

$$D^+ = \sum_{i=1}^5 \sqrt{\sum_{j=1}^{n+1} (X_{ij} - X_j^+)^2} \quad (8)$$

D^-

$$= \sum_{i=1}^5 \sqrt{\sum_{j=1}^{n+1} (X_{ij} - X_j^-)^2} \quad (9)$$

$$\text{Rank Index} = R.I = \frac{D^-}{D^+ + D^-} \quad (10)$$

Rank	Membership Function
Very Low (VL)	(0.00, 0.05, 0.15, 0.20, 0.25)
Low (L)	(0.20, 0.25, 0.35, 0.40, 0.45)
Medium (M)	(0.40, 0.48, 0.54, 0.60, 0.65)
High (H)	(0.60, 0.68, 0.74, 0.80, 0.85)
Very High (VH)	(0.80, 0.88, 0.93, 0.97, 1.00)

TABLE 1: Transformed Fuzzy Membership Functions

3.4 Phase 4:

In phase 4, clustering is formed. The CH announces itself as the CH within its transmission range; the other nodes in that region will be associated with the CH by sending a joining request as shown in Fig. 2(b). Then the CH creates TDMA scheduling depending upon the number of node members associated with it. CHs are not changed in every round in order to minimize overheads due to the set-up phase. Change of CHs depends upon a threshold with a value set to 0.011. When the selected CH threshold value is smaller than the other neighboring nodes, the re-clustering is performed.

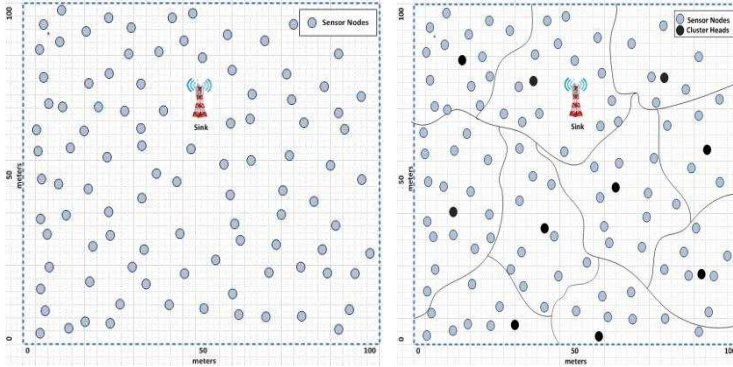


FIGURE :2 (a) Random deployment of SNs in a WSN field (b) Clustering formation in WSN field

3.5 Phase 5:

A communication mechanism is used after successful CH selection and formation. A threshold based intra-cluster and inter-cluster multi-hop communication mechanism is used, to allow a more realistic and practical model to be considered, as shown in Fig. 3(a). If the node distance from the CH is greater than 5m then the most suitable other node is selected to forward the data to the CH with the minimum energy usage possible. Similarly, if the distance of the CH from the sink is greater than 15m, then the other suitable CH is selected to forward the data to the sink with minimum energy usage possible.

3.6 Phase 6:

Finally, after every round completion, the sink moves its position by using sink predictable mobility with an octagonal trajectory or random mobility. In the same way SNs and CHs move their position in a random manner after every round. The sink random and predictable mobility is shown in Fig. 3(b).

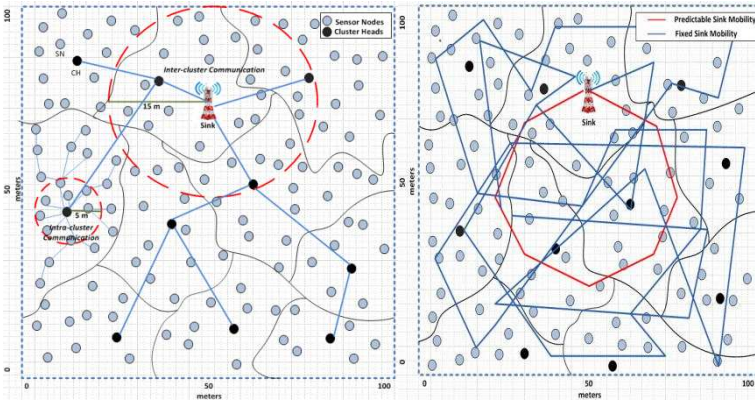


FIGURE 3: (a) Proposed threshold based intra-cluster and inter-cluster multi-hop communication model (b) Random and predictable sink mobility patterns

4 SIMULATION, RESULTS AND ANALYSIS

In this paper, results are compared with the most familiar LEACH [5] protocol and previous fuzzy environment based schemes [9]. Simulation parameters are given in Table II.

A simple radio model is considered [5]. In this radio model we assume that the radio channel is symmetric i.e. the energy required for

transmitting a message from node A to node B is similar to the energy required for transmitting a message from node B to node A for a given SNR. Energy consumption in data transmission over a distance d can be estimated from Eq. 11:

$$E_{TX} = \begin{cases} k * E_{elec} + k * \varepsilon_{fs} * d^2 & \text{if } d \leq d_o \\ k * E_{elec} + k * \varepsilon_{mp} * d^4 & \text{if } d \geq d_o \end{cases} \quad (11)$$

where, E_{elec} is the dissipated energy per bit, ε_{fs} is the energy used up in the amplifier if $d \leq d_o$ and ε_{mp} is the energy used up in the amplifier when $d \geq d_o$. Similarly, energy consumption in data collection is given by Eq. 12:

$$E_{RX} = k * E_{elec} \quad (12)$$

Parameters	Value
Simulation Area	100 x 100 m ²
No. of sensor nodes	100
Initial sink position	(50,75)
Initial energy of each node	0.5 J
Range of sensor nodes	20 m
Information data packet size	500 bytes
Hello control packet size	25 bytes
Data aggregation energy of node	50 pj/bit/report
Transmission energy (E_{TX})	50 nj/bit
Reception energy (E_{RX})	50 nj/bit
Transmitter amplifier (E_{amp})	100 pj/bit/m2

TABLE 2: Simulation Parameters

In this work, we have used different weighting criteria for each parameter, in order to investigate which scenario gives the best possible results; values of different scenarios are shown in Table III. Then the impact of change of node density and node mobility type (random and predictable mobility) is also simulated and discussed. We assume that the channel for data transmission is free of collision and interference. Further, SNs with the support of CHs send data to the sink by continuously monitoring the environment.

Criteria	S _{C1}	S _{C2}	S _{C3}	S _{C4}	S _{C5}
Residual Energy (C_{w1})	0.6	0.1	0.1	0.1	0.1
Node energy consumption rate (C_{w2})	0.1	0.6	0.1	0.1	0.1
Node Density (C_{w3})	0.1	0.1	0.6	0.1	0.1
Avg. distance between neighbors (C_{w4})	0.1	0.1	0.1	0.6	0.1

Distance from sink (C_{ws})	0.1	0.1	0.1	0.1	0.6
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TABLE 3: Criteria Weight

Fig. 4 indicates the number of dead nodes vs. the number of rounds. As the result shows, our proposed scheme outperforms previous protocols. This is because of threshold based CH selection, minimizing hello control packets, and the threshold based multi-hop communication model. Hence the scheme plays a vital role to increase the network lifetime. Table 4 depicts that the First Node Dead (FND) (network stability) in LEACH is 545 rounds, and the Last Node Dead (LND) (network lifetime) is around 1029 rounds. Similarly, the network stability of previous fuzzy schemes is 589 rounds and a network lifetime is 1435 rounds. On the other hand, our proposed fuzzy-TOPSIS protocol has much better results than the LEACH and previous fuzzy based protocols. We have simulated different scenarios in our proposed scheme in order to evaluate which scenario has the best possible results.

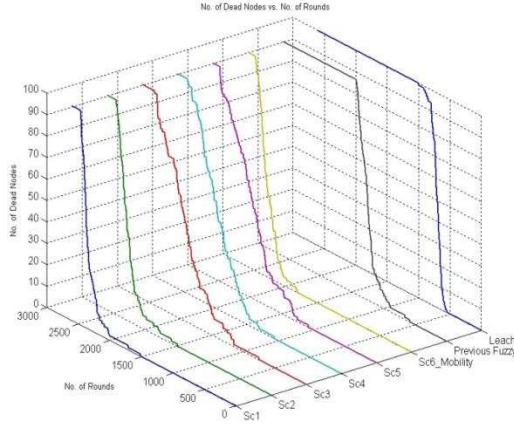


FIGURE 4: Number of Dead Nodes vs. number of rounds

As Table 4 indicates, in our proposed scheme scenario 1 and 2 have better results in terms of network stability than scenario 3, 4 and 5. This is because energy is the main and crucial criterion for WSN, so more weight assignment to remaining energy or energy consumption rate results in a higher network stability and lifetime.

According to [11], the WSN is considered to be dead if the first node is dead (network stability). Therefore, when predictable sink mobility with octagonal trajectories is introduced in scenario 1, the network stability increased drastically to around 1806 rounds. It is also clear from Table

4 that the higher the network stability and lifetime, the more packets are sent to the CH and sink by the SNs. So, we propose the Fuzzy-TOPSIS based CH selection is made with higher weight to the remaining energy and predictable sink mobility with octagonal trajectories. The remaining results are compared with LEACH, previous Fuzzy schemes and that based on our proposed scheme (scenario with best outcome).

Protocol	FND	LND	Packets to CH	Packets to Sink
LEACH	545	1029	48225	7725
Previous Fuzzy	689	1435	98930	14590
Scenario 1	1516	2467	199230	33841
Scenario 2	1479	2458	191934	34366
Scenario 3	749	2410	163409	27002
Scenario 4	1064	2436	162042	34454
Scenario 5	1078	2482	167254	31507
Scenario Mobility	1806	2473	194355	33649

TABLE 4: Network stability, lifetime and throughput for different protocols and scenarios

Fig. 5 demonstrates the number of CH changes per round. As the result shows, there is a low average number of CHs per round in the LEACH protocol but there is a rapid change in CH selection, while CH change in previous fuzzy based protocols is not rapid as in LEACH but uses a high percentage of CHs per round. However, in our proposed protocol CH change per round is smooth and uses a less number of CHs per round. Hence, it reduces hello control packet overheads. Table 5 shows that the average number of CHs per round in LEACH, previous fuzzy schemes and in our proposed scheme are 10, 18 and 14, respectively.

Protocol	Avg. no. of CHs per round
LEACH	10
Previous Fuzzy	18
Proposed Fuzzy TOPSIS	14

TABLE 5: Average number of CH per round

Fig. 6 shows that the CH change rate per round. Results indicate that: there is rapid change in CH selection in the LEACH protocol; moderate CH change in the previous fuzzy based protocol; while in our proposed protocol CH change rate per round is very low. Therefore, our protocol reduces hello control packet overheads.

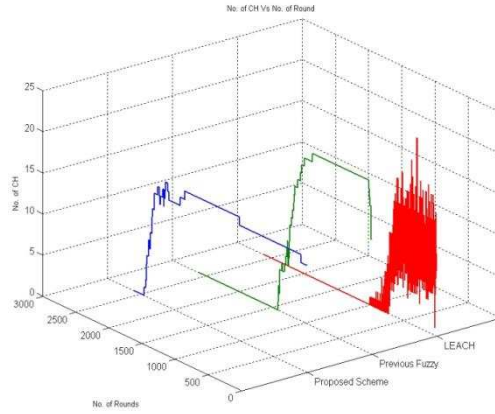


FIGURE 5: Average number of CH per round

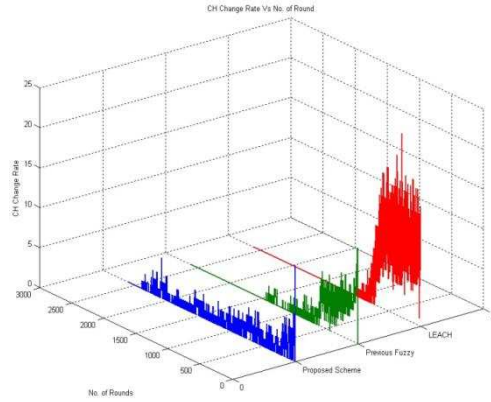


FIGURE 6: CH change rate per round

Fig. 7 shows that the total number of packets sent to the sink (network throughput) is much higher in our proposed scheme than the LEACH and previous fuzzy based protocols because of higher network lifetime. Quantitatively, it shows that the total number of packets sent to the sink in LEACH, previous fuzzy protocols and in our proposed scheme are 7725, 14590 and 33841, respectively.

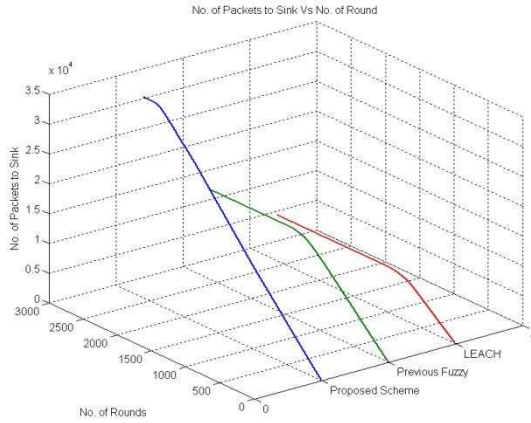


FIGURE 7: Number of packets to the sink

Fig. 8 indicates that the total number of packets sent to CHs by their neighboring SNs is much higher than the LEACH protocol and previous fuzzy environment based protocols because of higher network lifetime in our proposed scheme. Table 6 indicates the total number of packets sent to the CHs and sink for different protocols. Quantitatively, it shows that total number of packets sent to the CHs in LEACH, previous fuzzy protocols and in our proposed scheme are 48225, 98930 and 199230, respectively.

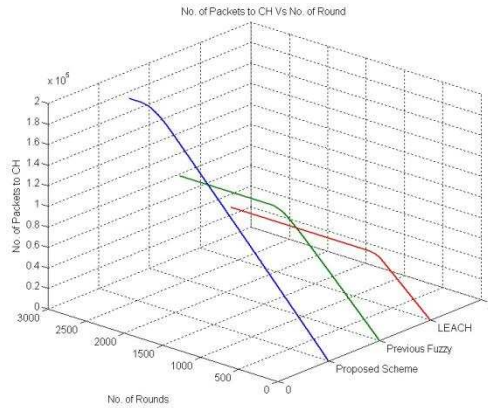


FIGURE 8: Number of packets to the CHs

Fig. 9 displays the network energy consumption per round. It is clear from Fig. 9 that the network energy consumption per round is less as compared to the LEACH protocol and previous fuzzy based protocols. This is because of threshold based CH selection, minimizing Hello control packets, and the threshold based multi-hop communication model. Quantitatively, the average network energy consumption per round in the LEACH protocol, previous fuzzy schemes and in our proposed scheme are: 0.05, 0.035 and 0.02, respectively.

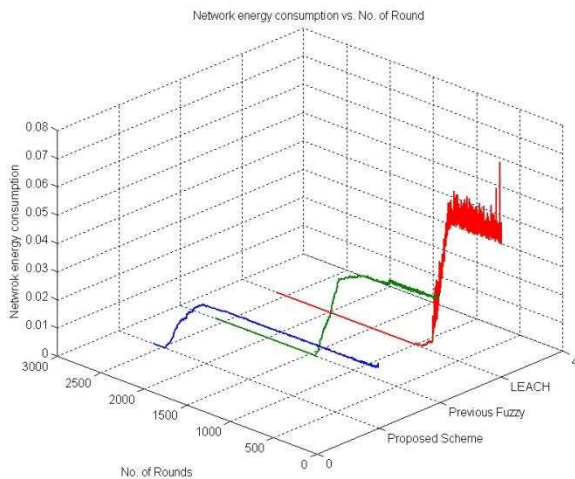


FIGURE 9: Average network energy consumption per round

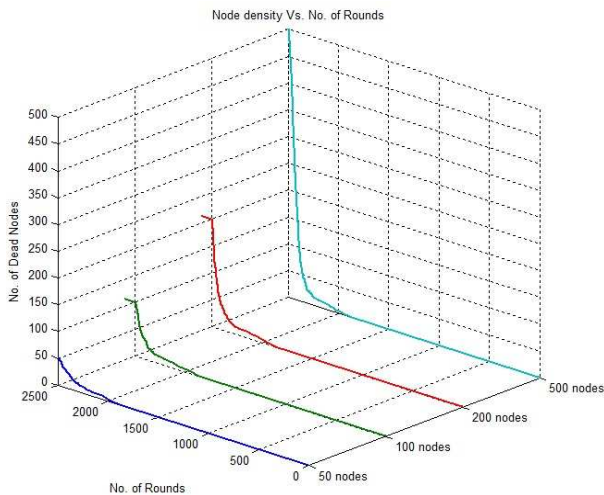


FIGURE 10: Impact of node density over network lifetime

In Fig. 10 the impact of node density in our proposed scheme is simulated and the result shows that with increase in the number of SNs there is little increase in network lifetime. On the other hand the number of packets to the sink (network throughput) directly depends on the node density. This is due to the percentage of CHs directly depending upon the node density.

Fig. 11 displays the impact of different types and node mobility strategies on network stability and lifetime. It is clear that only sink predictable and random mobility have much better results as compared to the other mobility types. This is because of: the more frequent CH and SN position and topology changes; more overhead in terms of Hello control packets; and increased processing overheads. This in turn causes more numbers of packets to be dropped and so results in a reduction in WSN network lifetime.

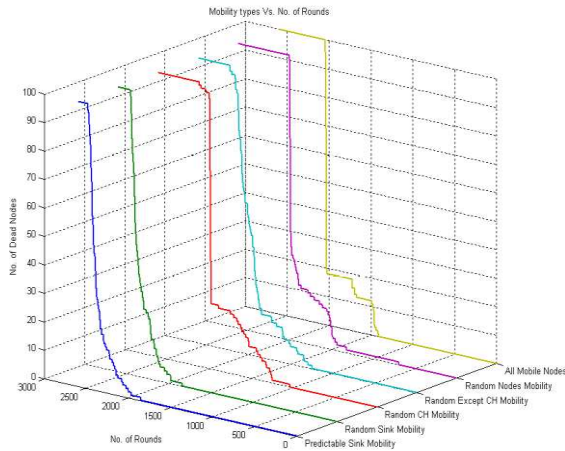


FIGURE 11: Impact of different types and node mobility strategies over WSN lifetime

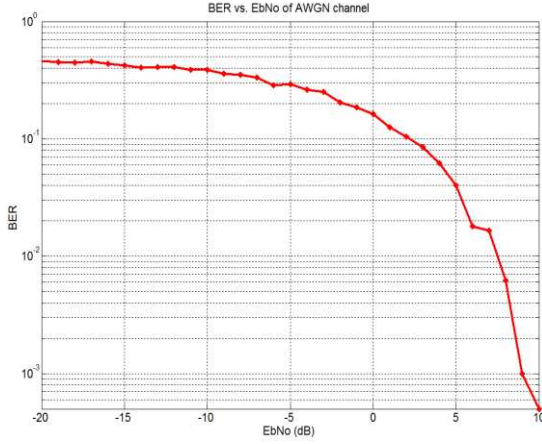


FIGURE 12: BER vs. EbNo for the proposed scheme

In this paper, all previous results discussed were based on communications that were free of interference and collision. In order to extend the depth of analysis, we have added an Additive White Gaussian Noise (AWGN) channel to the model in LEACH, previous fuzzy schemes and in our proposed scheme. We have also used Binary Phase Shifting Key (BPSK) digital modulation. The sensor nodes transmit at a power level varying between 10 mW to 15 mW (-20 dB to -18 dB), while the receiving end uses the maximum likelihood detection criterion to demodulate and extract the transmitted information. Fig. 12 shows the comparison of Bit Error Rate (BER) with Energy per Bit to noise power spectral density ratio (E_bN_o) for our proposed scheme.

Fig. 13 demonstrates the impact of the AWGN channel in our proposed scheme. It is clear from the figure that the overall network lifetime is reduced when we introduce the AWGN channel in LEACH, previous fuzzy schemes and in our proposed scheme. However, our proposed scheme with the AWGN channel still has a much better network lifetime when compared with the LEACH and Previous Fuzzy based schemes without the AWGN channel.

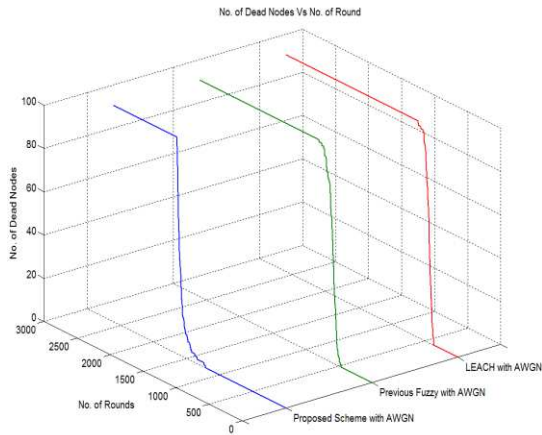


FIGURE 13:Comparison of proposed scheme with AWGN channel

Table 6 compares our proposed scheme with other criteria based WSN schemes. It is clear from the table that our proposed scheme outperforms previous protocols in terms of network stability and lifetime. This is because of threshold based CH selection to minimize hello control packets, sink predictable mobility and use of a threshold based inter-cluster and intra-cluster multi-hop communication model.

Protocol	No. of Parameters	Parameter Type	FND	LND
Fault Tolerant Election Protocol (FTEP) [12]	1	Remaining Energy	565	1123
Improved-LEACH [13]	2	Remaining Energy and coverage	556	1179
Cluster-Head Election Algorithm Using a Takagi-Sugeno (CHEATS) [14]	2	Remaining energy and distance from Sink	616	1125
Fuzzy based Energy Efficient Clustering [15]	2	Residual energy and node centrality	634	1148
Hybrid, Energy Efficient Distributed clustering (HEED) [07]	2	Node residual energy and node degree	685	1276

Improved Fuzzy Unequal Clustering (IFUC) [16]	3	Residual energy, distance to sink and local density	803	1319
Analytical Hierarchy Process (AHP) [17]	3	Energy, mobility and the distance of nodes to the involved cluster centroid	775	1398
Previous Fuzzy [9]	3	Residual energy, number of neighbors, distance from base station	589	1435
Decision Tree (DT) [18]	4	Distance of a node from the cluster centroid, remaining battery power, degree of mobility, and vulnerability index.	802	1619
Proposed Scheme	5	Residual energy, node energy consumption rate, number of neighbor nodes, average distance between neighboring nodes and distance from sink	1806	2473

TABLE 6: Comparison with previous criteria based schemes

5 CONCLUSION

In this research paper, we recommend a routing algorithm for Cluster Head selection based on Fuzzy-TOPSIS with predictable sink mobility octagonal trajectory. We have considered five criteria, including residual energy, node energy consumption rate, number of neighbor nodes, average distance between neighboring node and distance from sink. Threshold based intra-cluster and inter-cluster multi-hop communication is also considered. Simulation results indicate that, without an AWGN channel model, the network lifetime of our proposed scheme increased as compared to LEACH and previous fuzzy based schemes by around 140% and 72%, respectively. With an AWGN channel model, the

network lifetime of our proposed scheme increased as compared to LEACH and previous fuzzy based schemes by around 60% and 15% ,respectively. On the other hand, impact of node density on WSN lifetime is very negligible and hence our scheme provides a robust network as well.

In future work, CH selection based on a Fuzzy Flexible-TOPSIS (Fuzzy F-TOPSIS) scheme is suggested which is shown to enhance the ability to deal with vagueness in the Fuzzy TOPSIS method.

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